Growth of Ethanol in the USA including Regional Feedstock Availability

Doug Cameron
Khosla Ventures

Cellulosic Ethanol Technology Forum
and Roundtable Discussion
FEBRUARY 15 (THURSDAY), 2007
South Coast AQMD Headquarters Auditorium

Current ethanol technology

- **Yeast used to ferment glucose or sucrose**

  For glucose,

  $C_6(H_2O)_6 \rightarrow 2\ C_2H_6O + 2\ CO_2$

  (Y = 0.51 g/g)

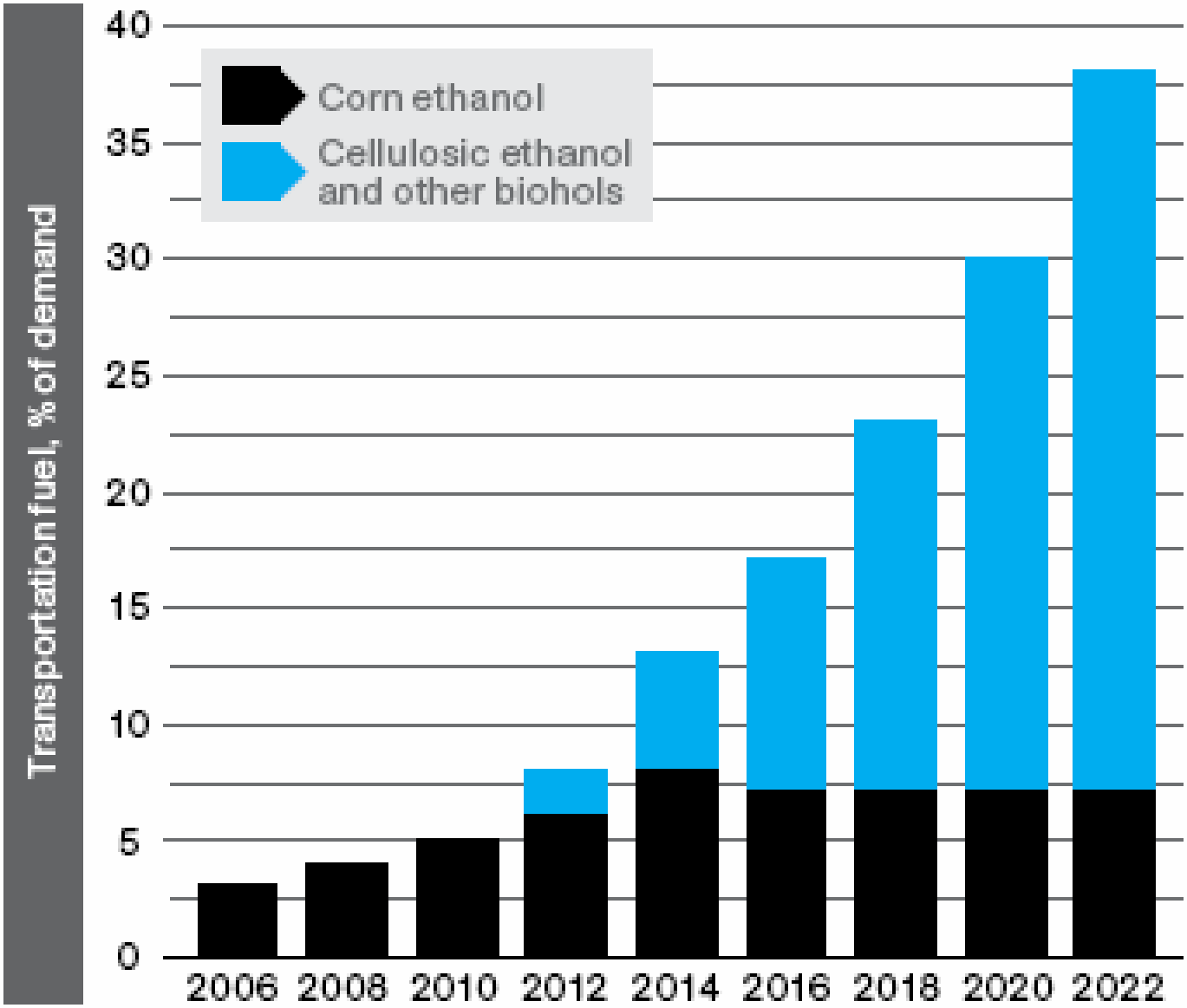
  For sucrose,

  $C_{12}(H_2O)_{11} + H_2O \rightarrow 4\ C_2H_6O + 4\ CO_2$

  (Y = 0.54 g/g)

- **Enzymes used to hydrolyze starch to glucose**

- **Natural gas, coal used to provide process energy**



WIRED, October 2006

How will we get there and what feedstocks will we use?

TWO [or more] roads diverged in a yellow wood, …

(With apologies to Robert Frost, The Road Not Taken)

Pretreatment --- hydrolysis --- fermentation

Pretreament --- simultaneous hydrolysis and pretreatment

Pyrolysis --- chemical conversion

Pyrolysis --- fermentation (?)

Gasification --- chemical conversion

Gasification --- fermentation

Diversa and Celunol Announce Merger to Create a New Biofuels Industry Leader

- First company with fully integrated technologies for cellulosic ethanol production

SAN DIEGO, and CAMBRIDGE, Mass., Feb. 12 /PRNewswire-FirstCall/ -- Diversa Corporation (NASDAQ: DVSA) and Celunol Corp. today announced they have signed a definitive merger agreement to create a new leader in the emerging cellulosic ethanol industry.

The combined company will be the first within the cellulosic ethanol industry to possess integrated **end-to-end capabilities** in pre-treatment, novel enzyme development, fermentation, engineering, and project development. It will seek to build a global enterprise as a leading producer of cellulosic ethanol and as a strategic partner in bio-refineries around the world. At the same time, the company will continue to pursue broad market opportunities for specialty industrial enzymes within the areas of alternative fuels, specialty industrial processes, and health and nutrition, with a primary focus on enzymes for the production of biofuels.

Diversa-Celunol Press Release, continued

Celunol has recently commenced operations of the **nation's first cellulosic ethanol pilot facility in Jennings, Louisiana** and expects to complete a 1.4 million gallons-per-year, demonstration-scale facility to produce cellulosic ethanol from **sugarcane bagasse and specially-bred energy cane** by the end of 2007. In addition, Celunol's process technology has been licensed by Tokyo- based Marubeni Corp. and has been incorporated into BioEthanol Japan's 1.4 million liter-per-year cellulosic ethanol plant in Osaka, Japan -- the world's first commercial-scale plant to produce cellulosic ethanol from **wood construction waste**. The combined company plans to bring its first U.S. commercial-scale cellulosic ethanol plants into production in late 2009.

Mascoma Awarded New York State Contract to Build and Operate $20 Million Cellulosic Ethanol Demonstration Facility

CAMBRIDGE, Mass., and ROCHESTER, N.Y., Dec. 20 /PRNewswire/ -- Mascoma Corporation, a leader in cellulosic biomass-to-ethanol development and production, announced today it has received a $14.8 million award to build and operate a **biomass-to-ethanol demonstration plant** in Rochester, New York.

The project will focus on demonstrating "cellulose to ethanol" technology and industrial processes. International Paper Co., Cornell University, Clarkson University and the Natural Resources Defense Council join Mascoma and Genencor as part of a consortium supporting the project.

The facility is expected to operate using a number of New York State **agricultural and/or forest products as biomass, including paper sludge, wood chips, switch grass and corn stover.**

"Developing cellulosic ethanol for New York will have a measurable, positive impact on **farmers' income and greenhouse gas emissions** in the state."

Rather than fermenting biomass carbohydrates, what about gasifying biomass and then converting the gases to ethanol?

Glucose to synthesis gas:

$C_6(H_2O)_6 \rightarrow 6\ CO + 6\ H_2$

Lignin: $C_{10}H_{11}O_2$
Vegetable oil: $C_{57}H_{104}O_6$

Synthesis gas to ethanol:

$2\ CO + 4\ H_2 \rightarrow C_2H_6O + H_20$

RANGEFUELS

Range Fuels to Build First Wood Cellulosic Ethanol Plant in Georgia
Potential to Produce Over 1 Billion Gallons a Year

BROOMFIELD, Colo. and PALO ALTO, Calif., Feb. 7 /PRNewswire/ -- Range Fuels, Inc., a cellulosic ethanol company, today announced it will build its first ethanol plant in Treutlen County, Georgia. Founded by Menlo Park, California-based Khosla Ventures, Range Fuels estimates that this plant -- combined with others to follow -- will have the capacity to produce over 1 billion gallons of ethanol per year.

The first plant will create over **70 new jobs** for the area.

Wood waste from the state's millions of acres of indigenous **Georgia Pine** will be the main source of biomass for the **ethanol production**.

Range Fuels, Inc, Press Release, continued

It also completely **eliminates the use of enzymes**, which have been an expensive component of traditional cellulosic ethanol production.

Its innovative and proprietary technology transforms otherwise useless products such as wood chips, agricultural wastes, grasses, and cornstalks as well as hog manure, municipal garbage, sawdust and paper pulp into ethanol through a **thermo-chemical conversion process**. The company's system, K2, uses a **two step process to convert biomass to a synthetic gas and from there, convert the gas to ethanol**.

In addition to a broad range of biomass to select from, the K2 system is also modular. This range of system performance will allow the K2 to be placed **near the biomass location reducing transportation costs.**

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"The production of cellulosic ethanol represents not only a step toward true energy diversity for the country, but a very cost-effective alternative to fossil fuels." said Vinod Khosla, who recently state he could see cellulosic fuel prices **sinking to $1 per gallon within 10 years**.

Science 8 December 2006:
Vol. 314. no. 5805, pp. 1598 - 1600

Carbon-Negative Biofuels from Low-Input High-Diversity Grassland Biomass

David Tilman,1* Jason Hill,1, Clarence Lehman1

Biofuels derived from low-input high-diversity (LIHD) **mixtures of native grassland perennials** can provide more usable energy, greater greenhouse gas reductions, and less agrichemical pollution per hectare than can corn grain ethanol or soybean biodiesel. High-diversity grasslands had increasingly higher bioenergy yields that were 238% greater than monoculture yields after a decade. LIHD biofuels are carbon negative because net ecosystem carbon dioxide sequestration exceeds fossil carbon dioxide release during biofuel production. Moreover, LIHD biofuels can be produced on **agriculturally degraded lands** and thus need to neither displace food production nor cause loss of biodiversity via habitat destruction.

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LS9 Launched to Create Renewable Petroleum(TM) Biofuels

SAN CARLOS, Calif., Feb. 14 /PRNewswire/ -- LS9 Inc., the Renewable Petroleum Company(TM), announced its launch today. Founded in 2005, the company is pursuing industrial applications of synthetic biology to produce **proprietary biofuels**. LS9's products, currently under development, are designed to closely resemble petroleum derived fuels, but be renewable, clean, domestically produced, and cost competitive.

Summary and concluding thoughts

The transition from corn/starch to cellulosic biomass feedstocks is underway

There are several alternative technologies to ethanol
(Multiple diverging roads)

These different paths have different feedstock needs

There is much current effort on biofuels other than ethanol
(Two roads diverge again?)